BRUSH Instruments

BRUSH

MP MASTER
MA30163

#3

Oscillographs and Accessories

THE BRUSH DEVELOPMENT CO.
3405 PERKINS AVENUE • • • CLEVELAND 14, OHIO

Warranty

Each new Brush Instrument is warranted for a period of one year from the date of sale against defective material or workmanship. This warranty is void if the instrument has been repaired by unauthorized persons or if it shows evidence of abuse or misuse. If this instrument fails during the warranty period, write to The Brush Development Company, 3405 Perkins Avenue, Cleveland 14, Ohio, Att: Customer Service Department, stating the date of purchase of the instrument and, if possible, the nature of the defect. Shipping instructions will be given and the instrument may be returned to us by express collect. If examination reveals defective workmanship or material, repair or replacement will be made without charge and the instrument returned to you prepaid.

All Brush instruments which are modernized or completely overhauled, will also carry the above instrument warranty. In the case of instruments which are repaired but not completely overhauled, this warranty shall extend only to the actual parts of the instrument repaired and not to the instrument in its entirety.

The time required for the repair of our industrial instruments is normally less than one week. However, if an instrument is being used in an application where it is of vital importance, loaner instruments can be provided to be used while your instruments are undergoing repair. No charge is made for loaner instruments other than the transportation charge involved.

THE BRUSH DEVELOPMENT CO. **3405 Perkins Ave., Cleveland 14, Ohio**

F-462

THE BRUSH DEVELOPMENT COMPANY

Instrument Division

MANUFACTURERS OF...

- ★ *Direct Inking Oscillographs*
- ★ *AC Amplifiers*
- ★ *DC Amplifiers*
- ★ *Carrier Amplifiers*
- ★ *Surface Analyzers*
- ★ *Universal Analyzers*
- ★ *Contour and Displacement Analyzers*
- ★ *Strain Analyzers*
- ★ *Uniformity Analyzers*
- ★ *Universal Bridge Switches*
- ★ *Regulated Frequency Power Supplies*
- ★ *WOW Meters*
- ★ *Vibration Pickups*

and other acoustic and electronic instruments

Oscillographs and Accessories

Form 486 2M 1-51

Operating Information

Brush Oscillograph Equipment

The Brush Development Company

3405 Perkins Avenue Cleveland 14, Ohio. U. S. A.

Operating Information

SECTION I

For BL-902 and BL-902A Magnetic Pen Motors*

GENERAL DESCRIPTION

The magnetic pen motor is an instrument designed to make direct inked records of electrical potentials from DC to 120 cps. It consists of a D'Arsonval moving coil galvanometer element suspended in the field of a powerful Alnico magnet. The inking pen is attached to the upper end of the moving coil system (a-Fig. 1).

Ink is supplied to the pen from an inkwell located behind the pen (c) and is fed to the pen through a length of flexible plastic tubing. Several types of charts may be used with the pen motor, such as the strip chart similar to that used on the complete Brush Oscillographs, or a rotating drum chart. Lateral adjustment of the pen for centering purposes is provided by means of a lever (b-Fig. 1).

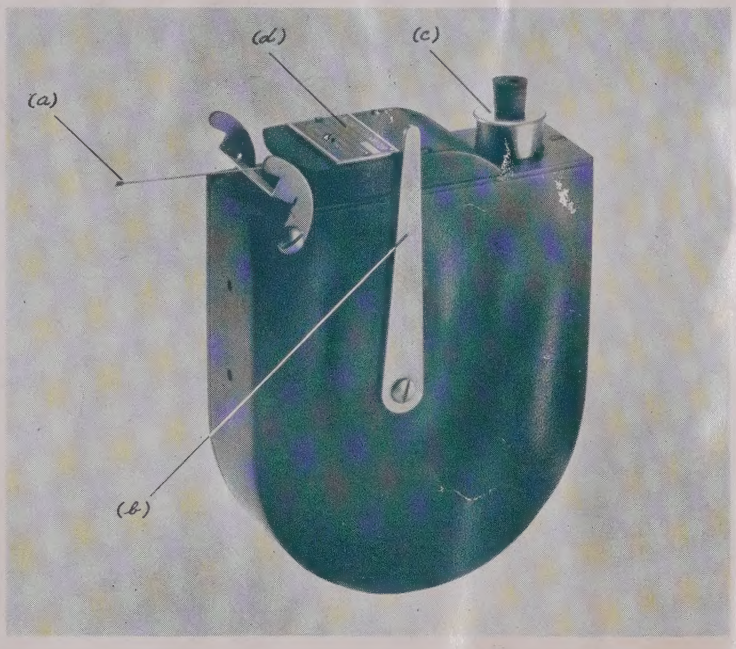

Figure 1

Two types of pen motors are available. The Model BL-902 is designed for use in single-channel Oscillographs where it is remote from other pen motors. The BL-902A is to be used in multi-channel applications where two or more pen motors are operating in close proximity, the magnetism of the magnet of the latter unit being adjusted to take into account the reinforcing action of other nearby magnets.

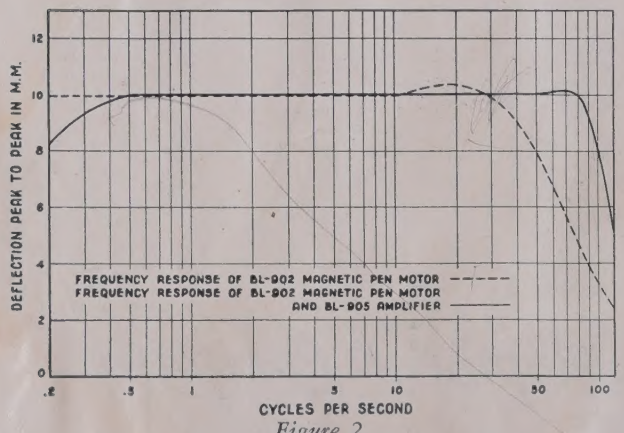

Figure 2

SPECIFICATIONS

(A) ELECTRICAL

1. Frequency Response — essentially uniform from DC to 30 cps, falling to 120 cps (see curve, Figure 2).
2. Minimum Sensitivity: — 1.1 mm per volt, 1.6 mm per milliampere (distances refer to deflections at pen point).
3. Impedance of Driving Coil: — 1500 ohms, resistive.
4. Driver Impedance: — 250 ohms for optimum damping, 500 ohms satisfactory.

*Patent 2478329

5. Recommended Amplitude of Pen Swing:—40 mm (max.) peak to peak up to 70 cps.; 20 mm (max.) at 120 cps.

(B) MECHANICAL

1. Net weight—4 pounds.
2. Dimensions—Height 5″; Width—4″ (not including pen); Thickness—1⅜″; Pen Overhang—1⅜″.
3. Minimum Spacing—1¾″ for mounting pen motors.
4. Mounting Holes—4 holes tapped 8-32; 2″ vertical spacing; ¾″ horizontal spacing.
6. Pen Length—3″.

OPERATION

The pen motor may be driven by a suitable amplifier, or, where sufficient voltage is available, directly from the source. When used without an amplifier, it should be kept in mind that the proper impedance (250 ohms) must be connected across the pen motor at all times. This is important in D. C. applications involving the opening and closing of switches, etc. A pen deflection of 1.1 mm per volt is obtained on direct operation, with a maximum input of 16 volts RMS for full deflection. In the usual type of operation, a circuit that removes the operating voltage and applies it across a 1500 ohm load resistor when the pen is not recording is advantageous both from the standpoint of convenience and pen protection.

The pen motor may be driven by many types of standard amplifiers. However, for optimum performance, the following factors should be taken into consideration. It is generally preferable to connect the pen motor in a cathode follower circuit similar to that shown in Figure 3 as this gives better impedance matching. The amplifier should also provide for some form of overload protection to assure that no signals greater than approximately 20 volts reach the pen motor. Failure to do this may result in pen breakage. Likewise if a uniform response at higher frequencies is desired, the amplifier must provide high frequency compensation. All of the above features are provided in the Model BL-905 Amplifier.

For occasional applications, it is desirable to operate the pen at one edge of the chart as the zero position to allow for greater unilateral deflections. Although the pen may be mechanically offset a considerable distance by means of the pen centering lever, (b) Figure 1, it is well to use this lever to bias the pen only within a few millimeters of the center position because of the stresses set up in the suspension system. However, the pen may be electrically biased to an extreme position without difficulty.

Four types of pens are manufactured for use with the BL-902 and BL-902A pen motors. Then pen furnished as standard equipment is model BL-915. This pen gives a medium line .010″ to .018″ in width. For precision work, a fine line pen, model BL-917, giving a trace of .005″ to .009″ wide, is available. For greater legibility at lower frequencies, the model BL-918 pen should be used. This pen has a metal tip and gives a line .024″ wide. The above types are all

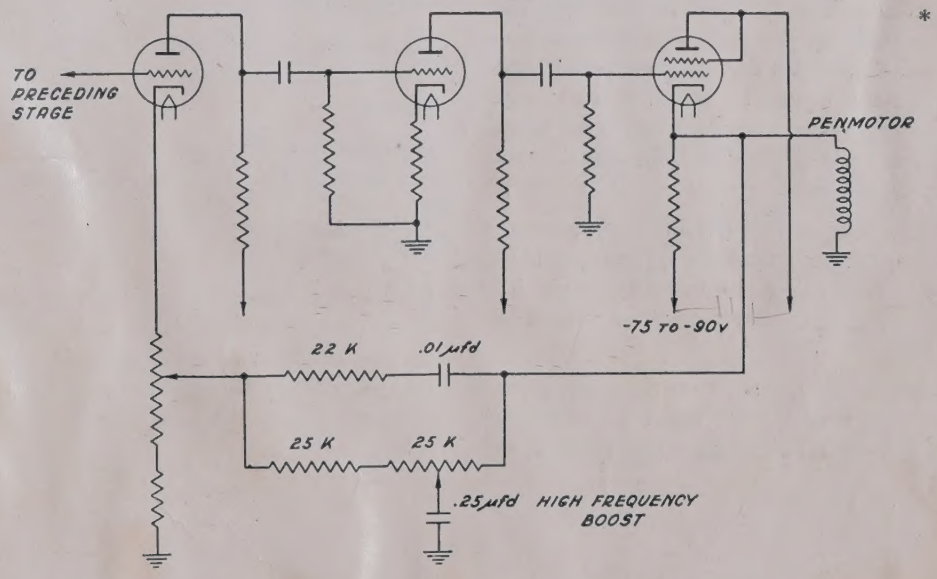

Figure 3

*Note: Proper bias must be supplied to the final stage.

3 inches long. Where greater amplitude is required, a special pen BL-921 having a length of 4¾" is available on special order. The use of this latter pen is not generally recommended, however, since the frequency response of the pen motors is drastically altered.

Two colors of ink are manufactured for use with the pen motor, red and green. These inks are specially made for the Brush pens and substitutes should not be used. Ink is available in 2 ounces, pint and quart bottles.

Signals giving less than 2 mm pen deflection may be affected by pen friction. This effect is reduced by operating at higher paper speed. If the signal is small, it is advisable to increase gain if possible.

MAINTENANCE

The magnetic pen motor should require no attention under normal use other than filling the inkwell and keeping the pen inking properly. Suggestions are given below for the care of the inking system.

The pen should never be left off of the paper for any length of time since the ink will dry and clog the pen. When the tip is in contact with the paper, capillary flow will prevent drying and clogging for considerable periods. If the instrument is not to be used for an extended period, however, it is well to wash out the inkwell and pen thoroughly and dry before storing. The inkwell should never be allowed to get very low since any sediment collected in the inkwell will then run into and clog the pens.

If the pens do become clogged, they usually may be cleared by *carefully* holding the point of the pen into the tip of a running water faucet and pressing a finger over the end of the faucet to build up a back pressure through the pen. Considerable finger pressure can be used without damaging the pen. In stubborn cases, the pens may be soaked in warm water prior to using pressure. Use of solvents is not recommended as they may dissolve the cement used to hold the glass points in place.

If the ink is subjected to freezing temperatures, a sediment may be precipitated which causes pen blocking. Users should take note of this fact when it is anticipated that the instruments will be subjected to extreme cold.

The tension of the pen point on the paper is controlled by the spring clip (a, Figure 4) which normally rests about 1/32" ahead of the pivot. If this

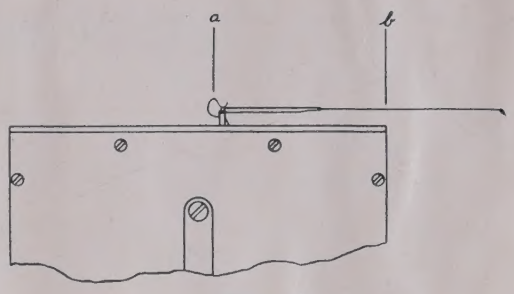

Figure 4

spring is bent or otherwise gets out of adjustment, it should be adjusted so that the tension at point (b, Figure 4) is about 1 gram. Fine nose pliers may be used to bend the spring.

If the pen motor is not operating properly, the trouble may be localized by testing the resistance of the coil at the pen motor terminals. This should be approximately 1500 ohms. Very high or very low readings would indicate an open coil or short circuit. Nonlinear response or poor wave form reproduction might indicate that the coil is rubbing against a pole piece. In any of the above cases, the unit should be returned to the factory as such repairs are difficult in the field.

Occasionally, an unavoidable overload may cause the pen to jump out of its support. It may be easily replaced by removing the metal cover over the base of the pen, (d, Figure 1). Care should be taken not to bend the tension spring (a, Figure 4) any more than is necessary to replace the pen. The plastic ink tubing may be led in from either side of the spring.

Precautions

The intense magnetic field of the pen motors may have an adverse effect on watches worn in the vicinity.

High potential differences between the terminals and pen motor housing or chassis should be avoided.

Mounting screws should not be driven more than 3/16" into the motor case.

Felt pads are provided on the inside of the pen lifter handles to minimize the danger of damage to the inking pen which might result on sudden overloads to the pen motor. Nevertheless surges may bend or break the pen, and in some cases, may burn out the coil.

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Operating Information

SECTION II

For BL-201 and BL-202 Oscillographs

GENERAL DESCRIPTION

The Model BL-201 Direct Inking Oscillograph is an instrument designed for the making of instantaneous, permanent chart records of a wide variety of electrical phenomena in the frequency range DC to 120 cps. The heart of the instrument is the magnetic pen motor, Model BL-902, specifications of which are presented in Section I. The oscillograph provides a chart drive mechanism for pulling the radially ruled paper at constant speed under the point of the pen, resulting in a record showing the variation of the phenomenon under study against time. Three chart speeds are available—5, 25, and 125 mm/sec, corresponding roughly to 1/5, 1, and 5 inches/sec.

The Model BL-202 Oscillograph is similar to the BL-201 except that it possesses two pen motors operating side by side, writing on double-channel paper. The pen motors in the BL-201 and BL-202 are not interchangeable due to the different magnetization, as described in Section I.

The oscillograph consists of a chassis housed in a black crackle metal cover. A hinged door permits access to the inkwell, pen, and chart paper for minor adjustments and notations without removing the cover, although the cover can be easily removed for reloading chart paper.

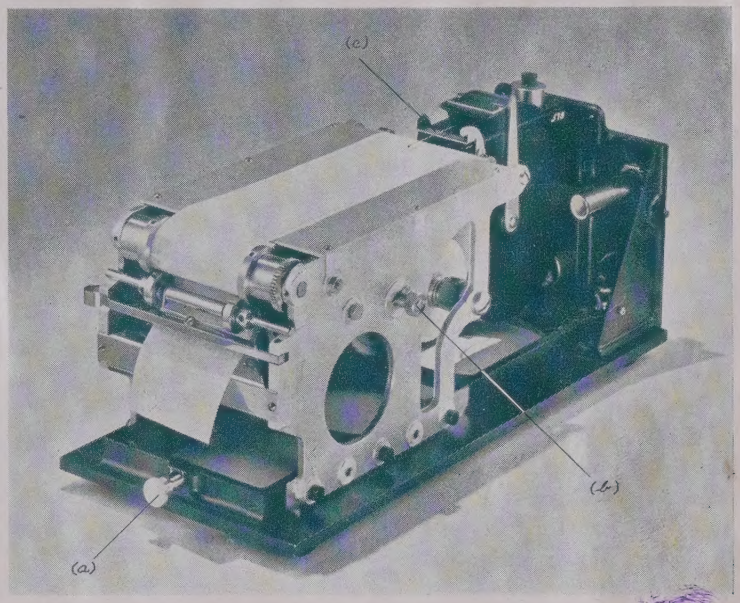


Figure 1

Figures 1 and 2 show the oscillograph with cover removed.

SPECIFICATIONS

BL-201 Single-Channel Oscillograph

1. Pen Motor ——— BL-902 Magnetic
2. Chart Paper ——— BL-908 — 2⅜" wide
   longitudinal markings spaced 1 mm
   transverse markings spaced 5 mm
3. Chart Drive Motor — 105 to 125 volt, 60 cycle 40 watts, synchronous
4. Chart Paper Speeds — 5, 25, 125 mm/sec.
5. Net Weight ——— 18 lbs.
6. Dimensions ——— 5⅞" high
   6½" wide
   14⅞" long
7. Fuse ——— 2 amp. Littelfuse, type 3AG

BL-202 Double-Channel Oscillograph

1. Pen Motor ——— BL-902A Magnetic
2. Chart Paper ——— BL-909—3 15/32" wide
   longitudinal markings spaced 1 mm
   transverse markings spaced 5 mm
3. Chart Drive Motor — 105 to 125 volt, 60 cycle 40 watts, synchronous
4. Chart Paper Speeds — 5, 25, 125 mm/sec.
5. Net Weight ——— 22 lbs.
6. Dimensions ——— 6⅞" high
   6½" wide
   14⅞" long
7. Fuse ——— 2 amp. Littelfuse type 3AG

OPERATION

The following procedure, which applies equally well to either the BL-201 or BL-202, should be followed when first placing the oscillograph in operation:

To load paper roll, remove cover by loosening knurled cover lock screw (a, Figure 1). The front may then be lifted upwards and the cover then slid forwards and off. Speed selector knob (b, Figure 1) must be all the way in for this operation.

Remove knurled paper roll nut (a, Figure 2) and slide new roll of paper on spindle so that the paper comes off the roll on the side nearest the pen motor. Raise the pen by operating the pen lifter (c, Figure 1) and draw the paper under the pen and over the writing table. The pressure roll may be released by operating the spring catch on the left side of the paper drive (b, Figure 2). The paper is then drawn over the drive roller at the front of the chassis and the drive roll. Care should be taken to see that the flats on both ends of the pressure roll shaft face down and are bearing properly before the roll is snapped shut.

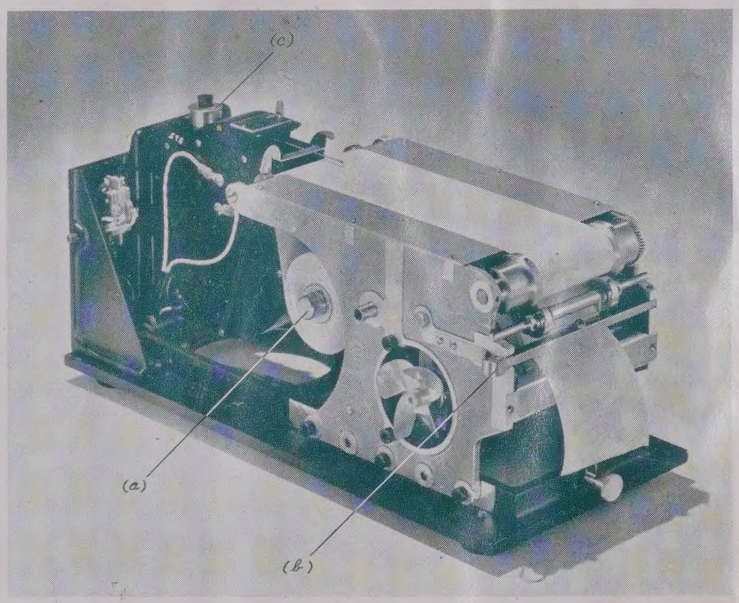


Figure 2

Fill inkwell (c, Figure 2) with Brush ink by means of the eye-dropper provided. Replace rubber stopper, force ink into pen by placing thumb over the hole in the stopper and pressing down. It may be necessary to repeat this process several times. Pen tip should always be left on the paper when the instrument is not in use as the capillary action prevents the ink from drying in the pen and clogging it.

The supplied power cord should be plugged into the recessed male socket at the bottom of the back panel. The chart drive requires 115 volt, 60 cycle current. The motor is turned on by means of the switch on the back panel (toggle switch for the BL-201, black pull-out switch for the BL-202). Chart speeds are selected by the selector knob (Figure 1). With the knob all the way in, the chart is driven at 5 mm/sec; with the knob in the intermediate position, a speed of 25 mm/sec. is obtained; the knob entirely out gives the maximum speed of 125 mm/sec.

Input to the oscillograph is applied to the four prong male connector on the back panel. Terminals 1 and 4 (large prongs) are connected to the pen motor. When using the BL-905 Amplifier, this connection is automatically made (see Section III). The on-off switch also controls the input to the pen motor so that it is not possible to operate the pen motor independently of the chart drive. When off, the input terminals are shunted by a 1500 ohm dummy load resistor to prevent sudden changes in the load of the driving circuit.

It is important to keep in mind that the inking pen is connected to the low side of the pen motor coil (top pen motor terminal, number 4 connector prong). It is advisable to keep the voltage between this terminal and ground as low as possible (see Precautions, Section I).

When used independently of the BL-905 Amplifier, care should be taken to prevent voltages of more than 20 volts from being applied to the pen motor. For proper damping, the pen motor should always be driven from an impedance of from 50 to 500 ohms, 250 ohms optimum. A more complete description will be found in Section I describing the pen motor proper.

MAINTENANCE

PEN—Should the pen become clogged, it usually can be cleared by inserting the tip under the end of a water faucet and placing the finger over the pen and faucet and, creating a back pressure through the pen. This problem is more completely discussed in Section I.

LUBRICATION—Normally the unit should not require lubrication, but if erratic operation of the chart drive system is observed, apply a very small amount of light oil to the bearings and vaseline to the gear teeth, etc. Excessive lubrication makes the unit collect dust and become gummed up.

FUSE—The 2 amp. Littelfuse is located on the back panel in a standard screw-in fuse holder. It may be easily replaced by removing the holder. If the fuse blows frequently, inspection should be made to locate faulty insulation.

PAPER DRIVE—The paper drive should function smoothly and quietly at all speeds. If a noisy or erratic action occurs, it is probably due to the fact that dirt or foreign material has found its way into the bearings of either the pressure rolls or the main drive roll at the front of the chassis. The condition may usually be corrected by removing the roll and cleaning the bearings. A small (No. 6) Allen Head wrench may be used to loosen the set screws on the two collars holding the rollers on the pressure roll assembly in place. The rollers may then be removed for cleaning, lubricating, etc. They should rotate freely with very little friction when correctly adjusted.

To remove the main drive roller, it is necessary to loosen the set screws holding the shaft in the chassis, and drive the shaft out to the side, after which it may be inspected to determine if the bearings are functioning properly.

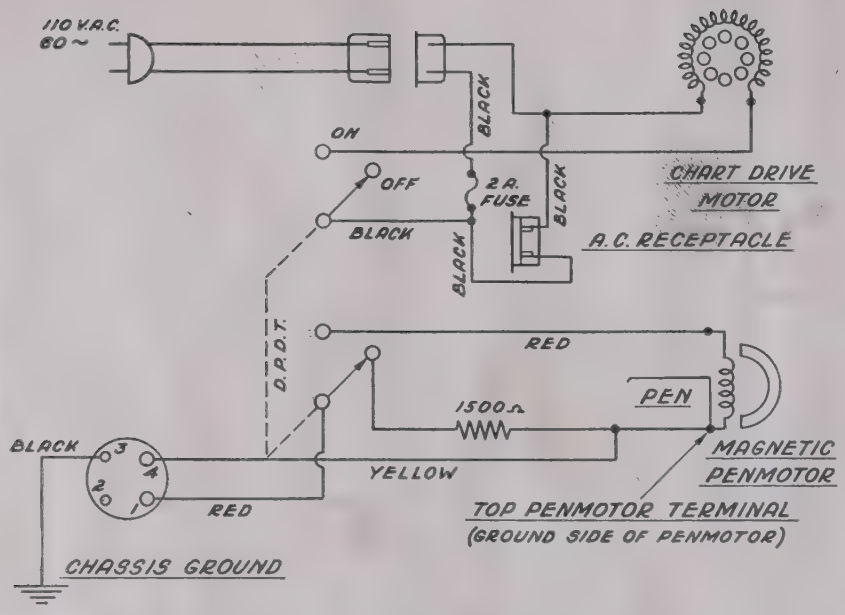
Should slippage occur, or should the paper have a tendency to travel to one side, the pressure roll should be inspected to ascertain if both rollers are bearing evenly and with sufficient pressure against the main drive roll. It may be necessary to bend the wire spring supporting the rollers slightly to compensate for any misalignment.

A sudden overload may cause a pen to jump out of its stirrup. The pen may be replaced by taking off the metal cover and re-inserting the pen in its support, as described in Section I.

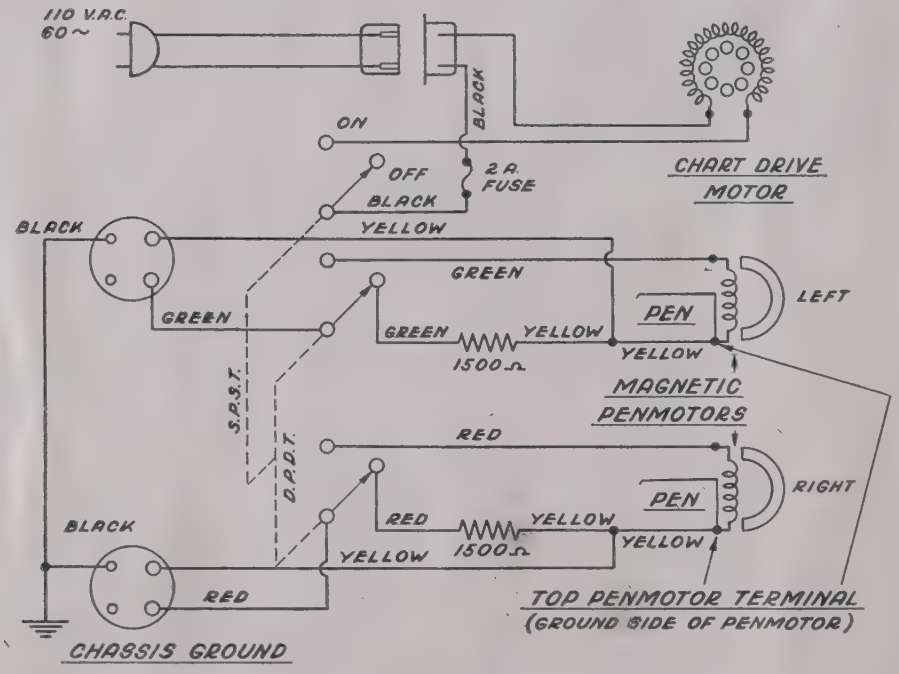
Precautions

Be certain that the shoulder on the cover lock screw (a, Figure 1) is fully engaged before attempting to carry the instrument by its carrying strap.

Watches or tools that will be affected by magnetism must be kept clear of the instrument because of the strong magnetic field of the permanent magnet.



OSCILLOGRAPH BL-201 CIRCUIT DIAGRAM



OSCILLOGRAPH BL-202 CIRCUIT DIAGRAM

Figure 3

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Operating Information

SECTION III

For BL-905 Amplifiers; BL-211 and BL-212 Oscillographs

GENERAL DESCRIPTION

The BL-905 Amplifier is specially designed for use with the BL-902 and BL-902A Magnetic Pen Motors. The amplifier consists of four stages of amplification, with a single ended 6V6 final stage and cathode follower output. A self-contained power supply operates from 105-125 volts, 50 or 60 cycles. A calibration circuit is included in the circuit so that the pen deflection of the oscillograph can be accurately correlated to the input voltage of the amplifier. The control panel on the top of the instrument contains a calibrating meter, calibrating voltage control, calibrating button, factor of 10 attenuator, and gain control (Figure 2). The back panel of the chassis consists of an "on-off" toggle switch, a four prong female connector, power plug, fuse holder, and a terminal for an external ground connection (Figure 3). The input jack of the amplifier is found on the front panel of the instrument. The amplifier is equipped with an adjustable high frequency boost so that the oscillograph-amplifier combination has an essentially uniform response from 0.5 to 100 cps (a, Figure 2).

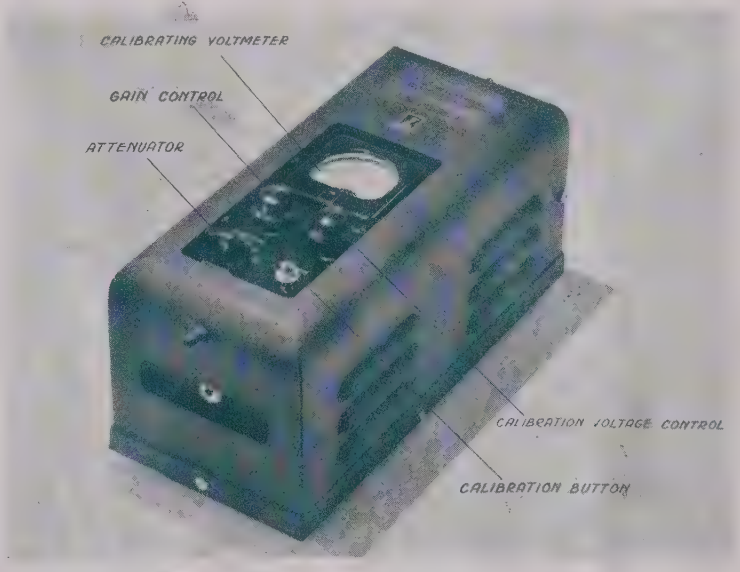

Figure 1

The maximum voltage gain of the amplifier is approximately 2000 times, giving full scale deflection of the oscillograph pen with inputs as low as 10 millivolts peak, or with the use of the attenuator, as high as 300 volts.

The combination of BL-201 Oscillograph and BL-905 Amplifier is known as Model BL-211; the BL-202 Oscillograph and two Model BL-905 Amplifiers is designated as the Model BL-212. When ordered together the amplifiers and oscillographs are individually calibrated for optimum frequency response. Accordingly, amplifiers and pen motors should not be interchanged unless the response characteristics are adjusted as described under "Maintenance."

The BL-211 and BL-212 Oscillographs are furnished with necessary power and connecting cables, as well as bottles of red and green charting ink and six rolls of chart paper.

The amplifier is housed in a black crackle metal cabinet whose appearance is complimentary to the oscillograph. The cover may be easily removed allowing ready access to tubes and other components. Quickly attached leather straps provide a convenient method for carrying both amplifier and oscillograph.

SPECIFICATIONS

AMPLIFIER, MODEL BL-905

Input Voltage Range ....001 to 300 volts
Output Voltage .....16 volts (max. RMS)
Voltage Gain .....2,000 times, maximum
Input Impedance .....10 megohms
Output Impedance ....approximately 50 ohms (not to be loaded with less than 1500 ohms)
Power Required .....105-125 volts
50-60 cycles
60 watts
Dimensions .....14¾" long
6¾" wide
7" high
Tubes Required .....3—6F5
1—6V6GT
1—5Y3
1—991
1—VR150
1—6H6
Fuse .....2 amp. Littelfuse, type 3AG
Net Weight .....20 lbs.
Shipping Weight .....23 lbs.

BL-211 SINGLE-CHANNEL OSCILLOGRAPH

Net Weight .....40 lbs.
Shipping Weight .....47 lbs.
Frequency Response ..flat ½ to 100 cps (see curve, Sec. 1)

Voltage Input for Full Scale Deflection .....010 to 300 volts, peak
Power Requirements ..105-125 volts
50-60 cycles
100 watts

BL-212 DOUBLE-CHANNEL OSCILLOGRAPH

Net Weight .....65 lbs.
Shipping Weight .....74 lbs.
Power Requirements ..105-125 volts
50-60 cycles
160 watts
Frequency Response ..flat ½ to 100 cps (see curve, Sec. 1)

Voltage Input for Full Scale Deflection .....010 to 300 volts, peak

OPERATION

A. PLACING THE INSTRUMENT IN OPERATION

The following procedure should be followed when first connecting the amplifier to the oscillograph. Be sure that the "on-off" switches of the units are in the "off" position. Then connect the amplifier and oscillograph with the short cable provided (in the case of the BL-212, the amplifiers should be connected to the proper pen motors as indicated by the sticker on the inside of the oscillograph cover. It may be necessary to ground the terminal at the back of the amplifier with the ground cable furnished, although the instrument can usually be used without making this connection. Set the attenuator on the "100" tap and connect both amplifier and oscillograph with the multi-plug AC power cord to a 115 volt, 60 cycle outlet. The inkwell should be filled, pen primed, and paper loaded according to instructions given in Section II. After switching on the amplifier and allowing it to warm up for a few minutes, the instrument is ready for use.

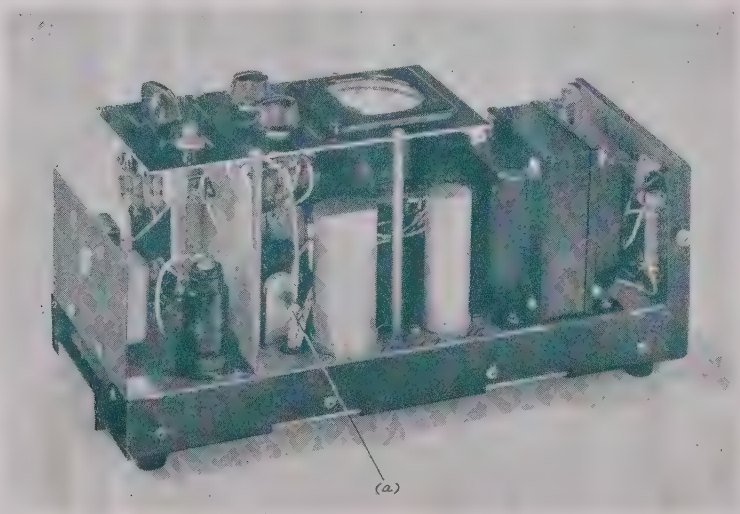

Figure 2

The input is supplied to the amplifier by a standard phone jack which plugs in the front of the chassis. It is generally a wise precaution to start all measurements with the attenuator set on the "100" tap, then increase sensitivity until the maximum pen deflection caused by the test voltage does not exceed 20 mm either side of cen-

ter. It is essential that the attenuator be set on "100" prior to removing or inserting input jack, or making any external changes in the input circuit. Failure to do so may temporarily paralyze the amplifier and cause the pen to jump out of its support and possibly damage the pen. Fine gain adjustment is provided by means of the "gain control" knob on the top panel of the amplifier (see Figure 2). Low, medium or high chart speed is selected by means of the knob on the side of the oscillograph chassis (see Section II).

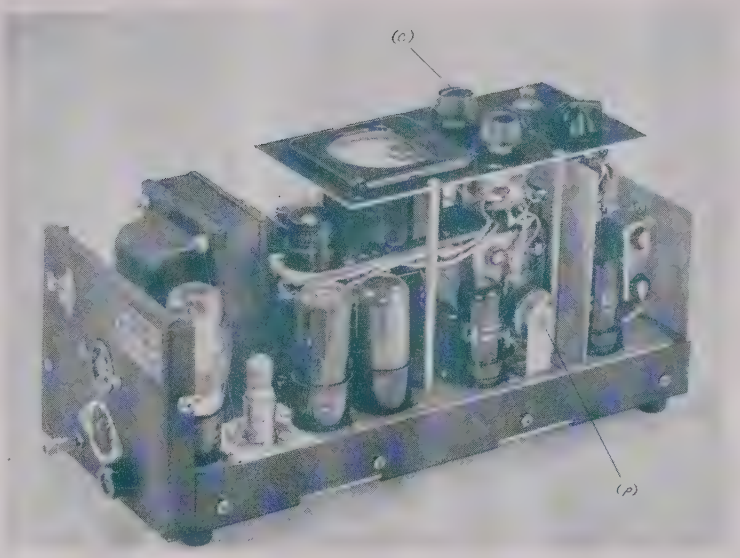

Figure 3

B. Calibration

Pressing the button marked "calibrate" on the amplifier top panel impresses a 60 cycle AC voltage on the input of the amplifier. This operation also removes the input jack from the circuit, so that the 60 cycle calibration signal is amplified and recorded in the usual manner. This feature provides a rapid and convenient method for adjusting the gain of the amplifier to produce any desired calibration of the instrument in terms of the relation between input volts and chart deflection in mm.

The following example will make this clear. Suppose it is desired to calibrate the instrument to 1 volt/mm. The "calibration voltage control" is adjusted until some convenient value, say 5 volts, is indicated on the voltmeter. The "calibrate" button is then pressed and the "gain" control adjusted until a deflection of 5 mm either side of center is obtained on the oscillograph chart. The instrument is now calibrated so that the peak value of any unknown input voltage can be found by multiplying the corresponding pen deflection by the attenuator setting. If a deflection of 13 mm one side of center is observed, and the attenuator is on the .01 tap, the input voltage is 13×.01, or .13 volts. Or if a deflection of 20 mm is caused by an unknown input with the attenuator on the 10 tap, the value of that unknown voltage is immediately found by multiplying 20 by 10, or 200 volts.

In general input voltages are found from the following formula:

Input volts (peak) = attenuator setting × displacement of pen (mm from center) × calibration in volts/mm.

The calibration circuit may also be used to determine the value of unknown input voltages with the gain at any arbitrary setting. Suppose for example that a pulse of 12 mm is produced on the oscillograph paper and it is desired to determine the magnitude of the input with the instrument uncalibrated. This can nevertheless be accomplished by pressing the "calibrate" button, and adjusting the "calibration voltage control" until a band 12 mm each side of center is produced. *Do not change the gain control in this case.* The peak input voltage is then equal to the voltmeter reading times the attenuator setting.

The calibration circuit of each amplifier is checked against an accurate laboratory voltmeter before leaving the factory. However, if the instrument has changed characteristics for some reason, it may be recalibrated according to the following procedure. After removing the cover of the amplifier, the amplifier voltage control potentiometer (P) will be found on the left side of the chassis, opposite the high frequency adjustment potentiometer (Figure 3). Connect the oscillograph to the amplifier. An AC signal of, say, 3.5 millivolts RMS, 60 cycles, as measured by an accurate vacuum tube voltmeter, is fed into the input of the amplifier and the gain adjusted until a deflection of 10 mm peak is observed on the oscillograph. The "calibrate" button is then pressed and the calibration voltage control (C) on the top panel of the amplifier is adjusted until an equal 10 mm band is traced on the chart paper. The voltmeter

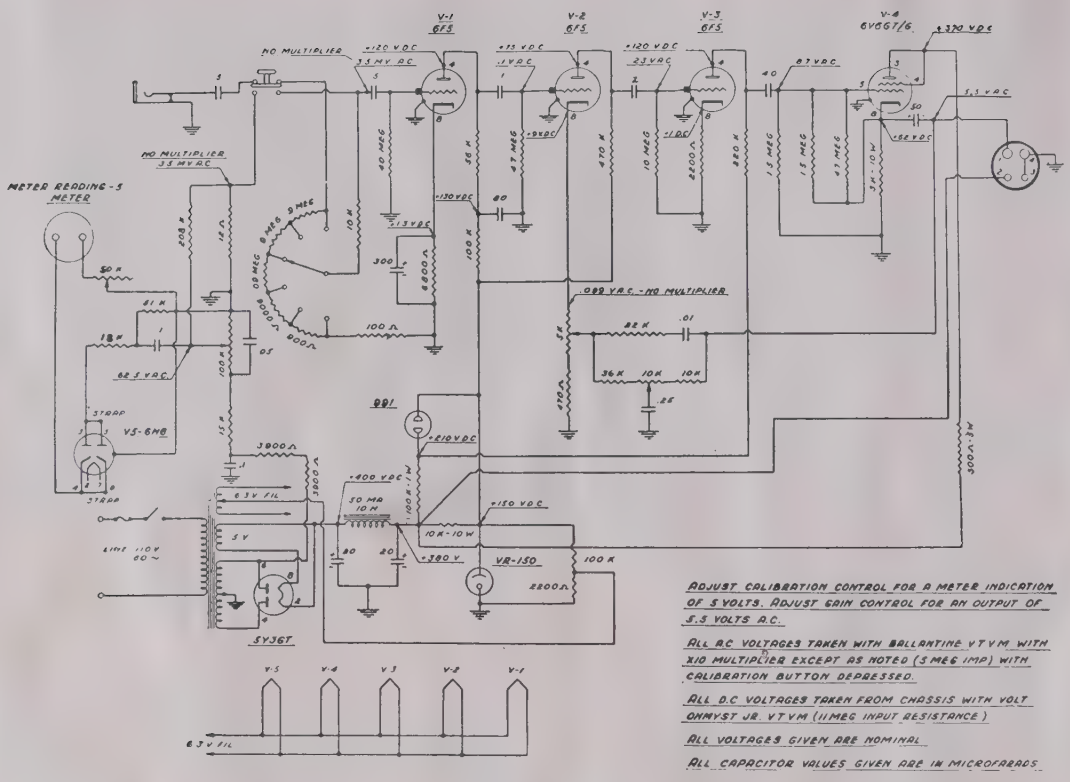
V-1 6F5
V-2 6F5
V-3 6F5
V-4 6V6GT/G
NO MULTIPLIER
METER READING-S METER
V5-6M8
5Y3GT
991
ADJUST CALIBRATION CONTROL FOR A METER INDICATION OF 5 VOLTS. ADJUST GAIN CONTROL FOR AN OUTPUT OF 5.5 VOLTS A.C.
ALL A.C. VOLTAGES TAKEN WITH BALLANTINE V.T.V.M. WITH X10 MULTIPLIER EXCEPT AS NOTED (5 MEG IMP.) WITH CALIBRATION BUTTON DEPRESSED.
ALL D.C. VOLTAGES TAKEN FROM CHASSIS WITH VOLT OHMYST JR. V.T.V.M. (11 MEG. INPUT RESISTANCE)
ALL VOLTAGES GIVEN ARE NOMINAL
ALL CAPACITOR VALUES GIVEN ARE IN MICROFARADS

Figure 4

control potentiometer (P) is then adjusted with a screw driver until the voltmeter on the amplifier reads 5 volts. Inasmuch as this control affects the magnitude of the calibrating signal, when the "calibrate" button is again pressed, the calibration voltage control (C) will probably need to be readjusted slightly to bring the band width back to 10 mm. Next, reset the voltage control potentiometer (P) to bring the voltmeter reading back to 5. Repeat this reciprocal adjustment until no further correction needs to be applied to either (P) or (C).

C. General

Due to the physical limitations of the pen and pen motor, the amplitude that can be used is a function of frequency. Therefore, some judgment must be exercised as to the maximum amplitude that can safely be used with each transient. Pen displacement up to 20 mm peak each side of center may be used efficiently for signals with frequencies up to 70 cps. An approximate maximum pen displacement for signals at 120 cps is about 20 mm overall.

MAINTENANCE

Service information for the BL-905 Amplifier is contained in the schematic diagram, figure 4, which gives static and operating voltages and circuit elements.

To adjust the frequency response of the amplifier to compensate it for use with a given pen motor, proceed as follows:

1. Introduce a known voltage having a frequency of 20 cps, into the amplifier and adjust gain control so that the pen deflection is ± 5 mm (medium or high chart speed).
2. Introduce an 80 cps signal of the same voltage and adjust the frequency compensation control (figure 2) to give the same deflection.
3. Repeat steps one and two until an adjustment is no longer necessary.

The Brush Development Company

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Operating Information

SECTION IV

On BL-206 and BL-216 Multichannel Oscillographs

GENERAL DESCRIPTION

The BL-206 oscillograph consists of six BL-902A magnetically matched penmotors in conjunction with a variable speed chart drive, housed in a dust proof metal cabinet. Chart paper is 12 inches wide, allowing a deflection of one inch each side of center for each pen. The chart paper may be rerolled, or allowed to fall freely from the drive roll. A manual speed selector lever allows the selection of either a high or low chart speed. Three types of motors are available, 3RPM, 6RPM and 30RPM, and in addition, interchangeable gears may be purchased, giving an overall speed range of approximately .01″ to 5″ per second.

A junction box is provided which permits the easy attachment of the amplifiers and which contains the on-off switch for the chart drive. When supplied with six matched BL-905 amplifiers, the oscillograph is designated as the Model BL-216.

There is supplied with the instrument—two (2) extra rolls of BL-907 chart paper and one (1) pint of recording ink.

SPECIFICATIONS

1. Dimensions	20¼″ High 17⅜″ Wide 16¾″ Deep
2. Net Weight	BL-206—165 Lbs. BL-216—270 Lbs.
3. Shipping Weight	BL-206—270 Lbs. BL-216—450 Lbs.
4. Chart Paper	Radially ruled 850 ft. rolls, 12″ wide
5. Chart Speeds	See table I
6. Voltage Requirements	105—125 volts, 50 to 60 cycles BL-206—140 watts BL-216—500 watts
7. Recording Elements	BL-902A Magnetically Matched Penmotors
8. Frequency Response	BL-216 — Essentially uniform ½ to 100 cps BL-206 — Essentially uniform DC to 30 cps; falling characteristics to 120 cps See curve, Section I

For electrical characteristics of penmotor and amplifier, see Sections I and III.

OPERATION

The recorder should be mounted in such a manner as to facilitate removal of the cabinet cover and to permit the opening of all doors.

To install or change a paper roll, proceed as follows (see fig. 3):

1. Open top, front, and side doors.
2. Raise the pen lifter bar. (a)
3. Release the drive tension roller (b) under the drive roller (c) by pulling out and down on the two handles. (d)
4. Remove the two large (e) and three small (f) knurled bolts and take off the side plate (g), removing the spring and collar from the take up spindle.
5. Take off both rolls and replace empty roll on the take-up spindle.
6. Place new roll on supply roll spindle and rethread according to Fig. 1 or 2.
7. Reassemble the side plate, engage the tension roller and lower the pen lifter.

Chart paper may be threaded according to either of the following diagrams.

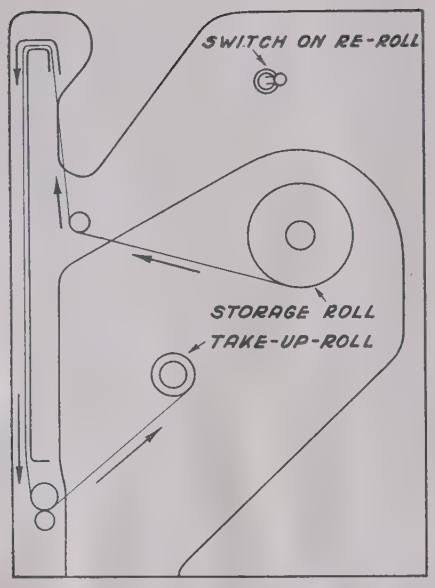

FIGURE 1. - RECORDER THREADED IN RE-ROLL POSITION

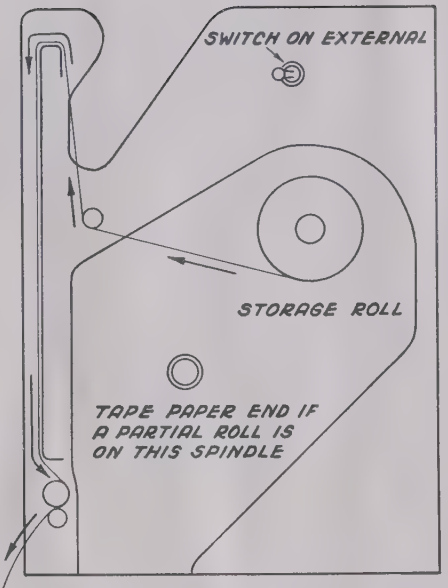

FIGURE 2. - RECORDER THREADED FOR EXTERNAL

The reversing switch located on the upper portion of the side plate (h, Fig. 3) should be thrown according to the type of paper drive desired, as shown in Fig. 1 or 2.

Two speeds are immediately available with any sprocket combination; they are obtained by changing the gear shift lever located at the lower right hand corner of the instrument (i, Fig. 3). This shift reduces the paper speed by a constant factor of 5. A reduction of 10:1 can be supplied if specified. In case the clutch does not disengage from the gear it is driving, reversing the motor for a fraction of a revolution will allow it to shift over freely.

If it is desired to change the chart speed to other values specified in Table 1, the motor sprocket must be changed. The following steps are recommended in making this change (see fig. 3).

1. Open side door.
2. With motor operating, run chain (j) off the motor sprocket (k).
3. Remove the sprocket by loosening the Allen set screws.
4. Replace with proper sprocket to give desired speed.

PAPER SPEED TABLES

		MOTOR SPEED 3 RPM			MOTOR SPEED 6 RPM			MOTOR SPEED 30 RPM		
			Low Speed Standard	Optional		Low Speed Standard	Optional		Low Speed Standard	Optional
No. of Teeth Roller Sprocket	*No. of Teeth Motor Sprocket*	*High Speed*	*5:1 Ratio*	*10:1 Ratio*	*High Speed*	*5:1 Ratio*	*10:1 Ratio*	*High Speed*	*5:1 Ratio*	*10:1 Ratio*
27	60	12½	2½	1¼	25	5	2½	125	25	12½
27	48	10	2	1	20	4	2	100	20	10
27	24	5	1	½	10	2	1	50	10	5
27	12	2½	½	¼	5	1	½	25	5	2½

All paper speeds in mm/sec.

30 RPM motor with 60 tooth motor sprocket and 5:1 reduction ratio is standard.

10:1 reduction; 3 or 6 RPM motor; and 12, 24 or 48 tooth sprockets are optional to customer's order.

Chart drive motors available for Six Channel Oscillograph: 30, 6 and 3 RPM;

Brush part numbers 103783-1, 103783-2, 103783-3 respectively.

Table 1

5. Make a chain to fit the new sprocket. An extra length of chain is supplied with each instrument, and extra links are easily added to or removed from the original chain. New chains should not be fitted too tightly as there should be a small amount of slack in the chain.

The BL-206 is provided with a length of color coded, six conductor shielded cable as shown in fig. 4. The shield is the common ground connection to all penmotors. A separate AC power cord supplies current to the chart drive motor.

Connections are made through a junction box, the circuit of which is shown in Fig. 5. Amplifiers are connected through the short length of cable provided to the 4-prong male connectors on the junction box. A diagram is furnished with the BL-216 showing the proper matching of amplifiers and penmotors.

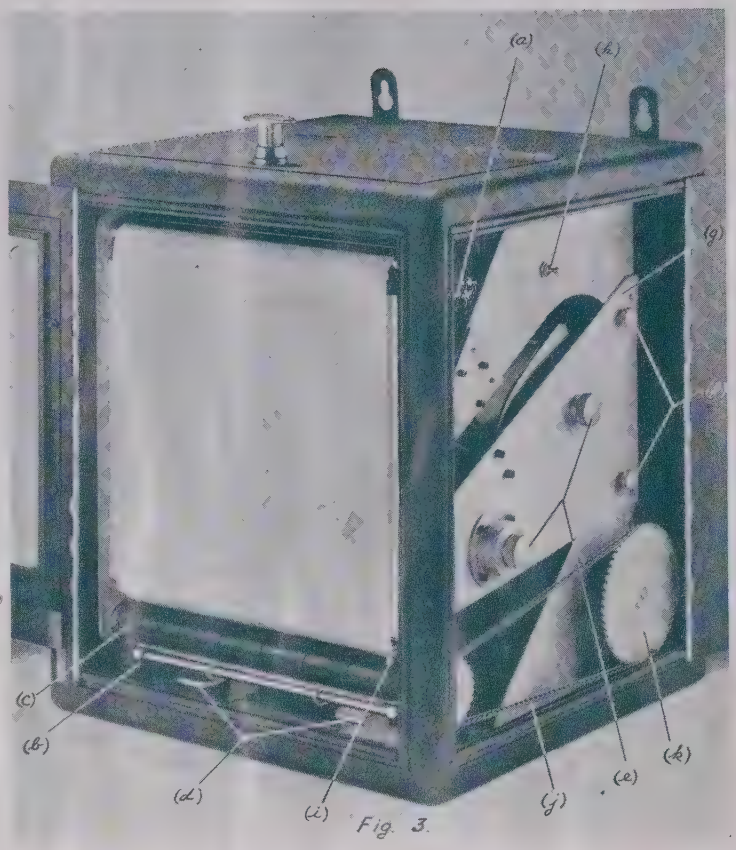

Fig. 3.

Electrical characteristics and operating data for penmotors and amplifiers are the same as those de-

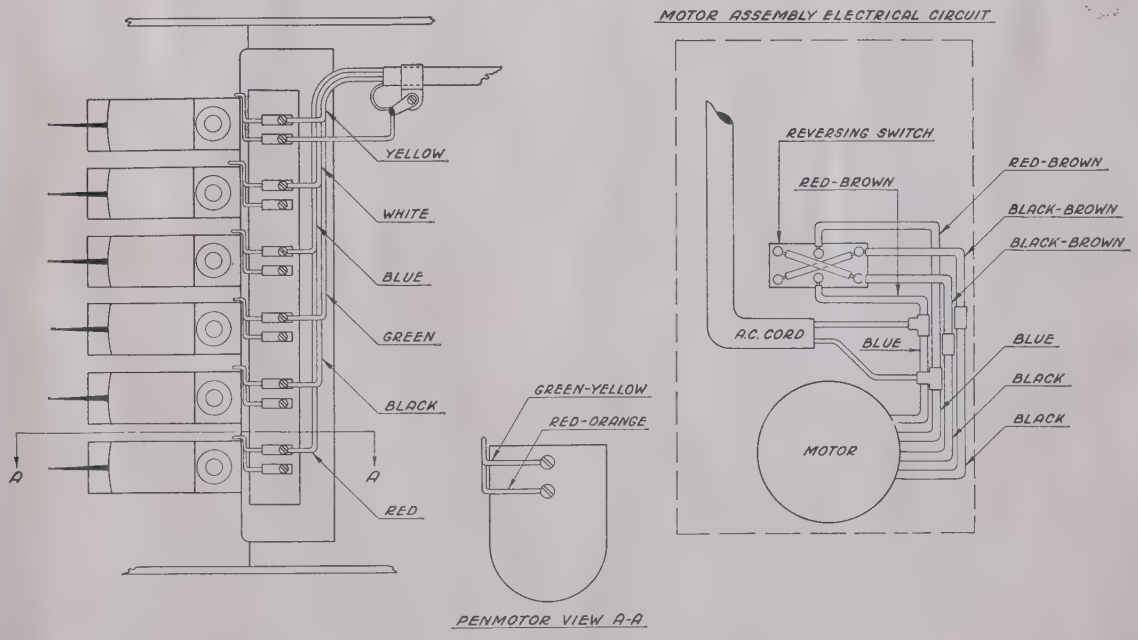

FIGURE 4.- RECORDER SCHEMATIC

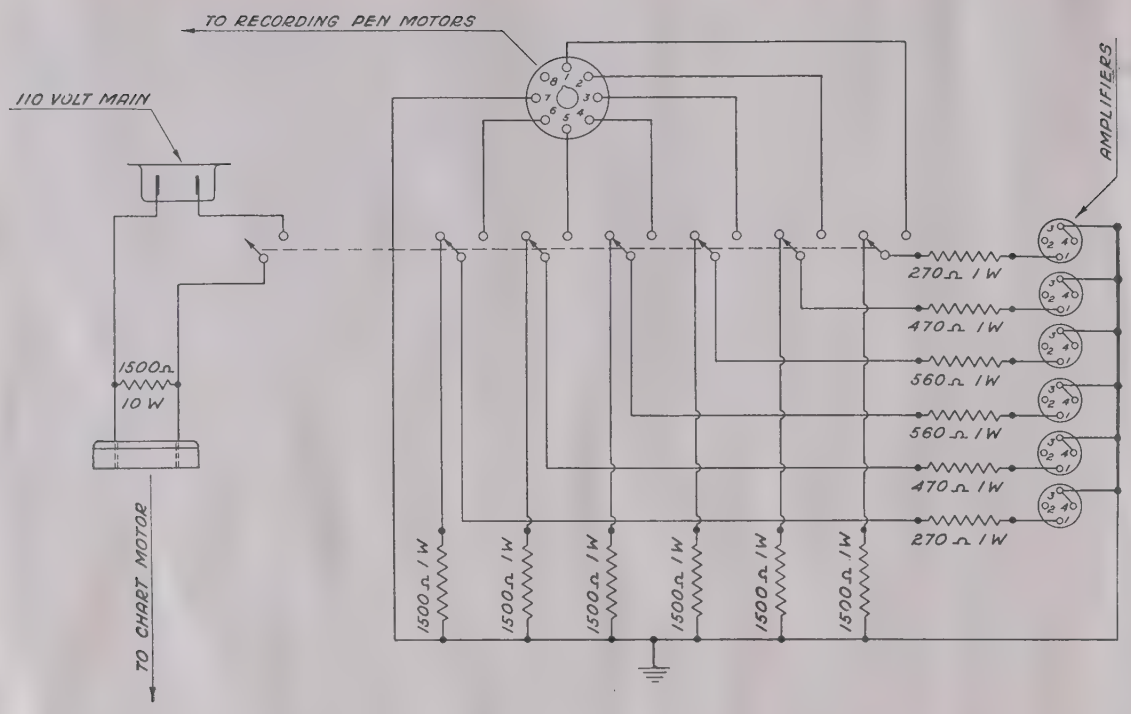

Fig. 5.

scribed in sections I and III. Before attempting to operate the multi-channel recorder, reference should be made to these sections.

The Six channel oscillograph is normally equipped with the medium line glass typed pen, Model BL-915. On special order, however, it can be furnished with fine line pens, Model BL-917, or coarse line, metal tipped pens, Model BL-918. The fine or medium pens are preferred for work involving high chart speeds or high frequency recording in order to avoid the possibility of smearing. For low frequency work at low chart speeds the coarse line pen may be used, giving a chart of greater legibility which may be more easily reproduced.

MAINTENANCE

If it becomes necessary to replace the rubber on the supply roll brake, it is important to adjust this spring to give a paper pull of the proper amount. If the majority of recording is to be done at chart speeds of less than 2 inches per second, the optimum pressure is such to produce a drag of from 4 to 6 pounds as the paper is pulled down over the pen table. If higher speeds will be used often, the tension should be from 2 to 3 pounds.

When applying the drive tension roller, it is important to apply both ends simultaneously. This results in even tension on the paper. The total torque required to drive the system, measured from the drive sprocket is 5 to 7 inch-lbs. with chart speeds of less than two inches per second and 3.5 to 5 inch-lbs. with speeds of more than two inches per second.

Remove any drops of ink on paper or drive roll which might result in smearing. The drive roll should be cleaned occasionally.

Since the six penmotors are magnetically matched for equal sensitivity, all penmotors should be returned to the factory for balancing whenever repairs are necessary to one or more penmotors.

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Strain Gage Theory

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STRAIN GAGE THEORY

Strain is defined as the unit change of shape or dimension of a body which results when forces are applied to it. This deformation may be either compressive or tensile and can be magnified by electrical means through the usage of a recently developed type of pickup called a wire strain gage. The function of this gage depends upon the physical properties of a wire. When a wire is stretched elastically, its length and diameter change. These changes affect a change in the electrical resistance of the wire. This variation in electrical resistance of the gage is detected, measured, and interpreted in terms of strain variation. Each wire gage is calibrated for a strain sensitivity. This sensitivity is expressed as the ratio of the unit change in resistance to the unit change in length of the wire. This ratio is also known as the gage factor, symbolically expressed as:

$$F = \frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}} \qquad (1)$$

where ΔR is the change in resistance in a total gage resistance R, and ΔL is the change in length in a total length of wire L. Figure 1 illustrates a single length of wire used as a strain gage to measure the strain uniformly effected along the axis of the specimen "A-A" and parallel to the wire.

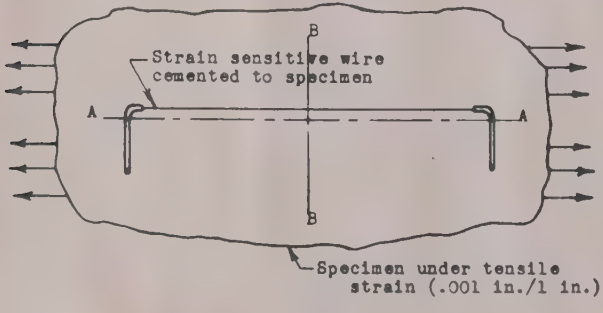

Figure 1

Let us assume that the resistance of the wire shown in Figure 1 is 100 ohms and that the tensile force applied to the specimen changes the resistance of the wire +.2 ohm. From equation (1) the gage factor or strain sensitivity of the wire becomes.

$$F = \frac{\frac{.2 \text{ ohms}}{100 \text{ ohms}}}{\frac{.001"}{1"}}$$

$$F = 2$$

Another way of expressing the sensitivity of this wire would be 2 micro-ohms per ohm per microinch/inch of unit strain. Thereby, 1000 microinches/inch of strain would cause a 2000 micro-ohm change for every ohm of wire resistance.

An additional strain applied along axis "B-B" (Figure 1) will not alter the strain measurement in the direction "A-A" (.001" per 1"). The response of the wire to this additional train is negligible primarily because of the small cross section of the wire used (.001" diameter - compared with several inches of length).

TRANSVERSE SENSITIVITY OF STRAIN GAGE

Practical considerations or resistance and gage lengths limit the use of a single length gage. Consequently, most wire gages are wound in grid form as shown in Figure 2. Examination of this type of gage shows that the looped ends can be subjected to a strain along axis "B-B" and therefore, the change in resistance of the gage will not be entirely due to the strain along the axis of the gage "A-A". The sensitivity of the gage to the strain in direction "B-B" is called the transverse sensitivity of the gage.

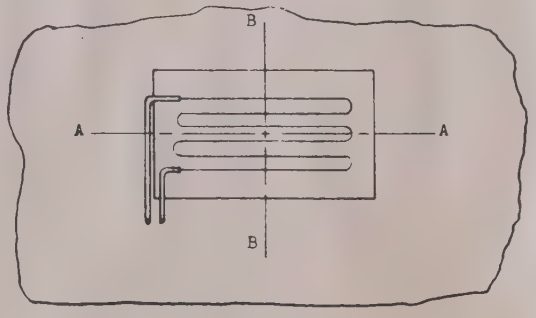

Figure 2

To illustrate simply the effect of transverse sensitivity on a strain measurement, let us consider Figure 3A.

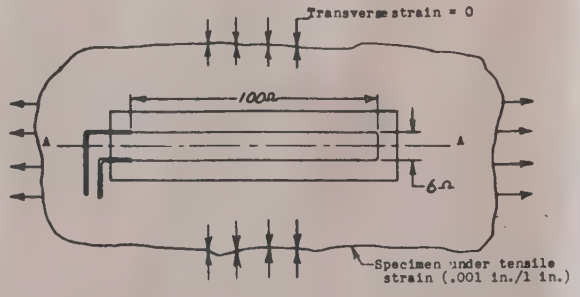

Figure 3A

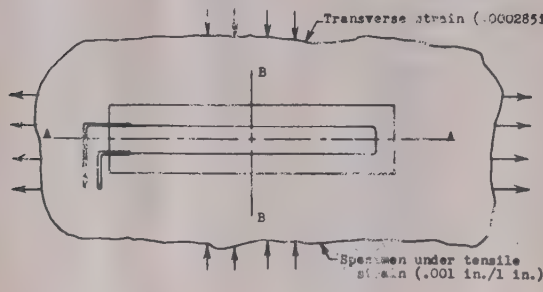

Figure 3B

The same wire used in illustrating a simple wire strain gage of Figure 1 is used to make up the wire strain gage shown in Figures 3A and 3B. Assuming a similar resistance change as was assumed in Figure 1, namely, .2 ohm per 100 ohms for .001" per inch strain, the gage factor of this gage is altered by the added resistance of the looped section. Since the transverse strain in the measurement illustrated in Figure 3A is zero, there is no change in the resistance of this looped section. The strain sensitivity (gage factor) of this wire gage is less than the strain sensitivity (2 0) of the gage shown in Figure 1.

$$F_1 = \frac{\frac{.2 + 0 + .2}{100 + 6 + 100}}{\frac{.001}{1}}$$

$F_1 =$ 1.94 (1.94 micro-ohm/ohm/ 1 microinch/in.)

In general, added resistance of the looped section diminishes the strain sensitivity of the gage.

The application of a strain along axis "B-B" alters the strain measurement made along the axis of the gage "A-A". In Figure 3B, compressive strain resulting from the strain applied along axis "B-B" acts on the looped section of the wire gage and decreases the resistance of that section. This change in resistance of the looped section is equal to -2.0 x 6 x .000285 = -.0034 ohm. Using the gage factor of the gage shown in Figure 3A the strain $\Delta L/L$ measured along the axis "A-A" becomes then +992 microinches. It can be seen from this illustration that a gage which is sensitive to transverse (normal or perpendicular to axis of gage) strain does not measure the true strain unless corrected.

$$\frac{\Delta L}{L} = \frac{\frac{+ .2 - .0034 + .2}{100 + 6 + 100}}{1.94}$$

$$\frac{\Delta L}{L} = +992 \text{ microinches/inch}$$

To determine the transverse sensitivity of the gage shown in Figures 3A and 3B, the gage was subjected to 1000 microinches/inch of tensile strain in the transverse direction while the strain along the gage axis "A-A" was maintained at 0. The change in resistance across the short looped section of the gage is

$$\Delta R_1 = R_1\left(\frac{\Delta L}{L}\right)F$$

$$\Delta R_1 = 6\ (.001)\ 2$$

$$\Delta R_1 = .012 \text{ ohms}$$

The transverse strain sensitivity of the gage becomes then

$$F_T = \frac{\frac{0 + .012 + 0}{100 + 6 + 100}}{\frac{.001}{1}}$$

$$F_T = .0583$$

It is observed that the transverse sensitivity of this gage is small compared with the axial sensitivity of the gage (.0583/1.94 or approximately 3%).

MANUFACTURER'S WIRE STRAIN GAGES

Commercially manufactured strain gages are calibrated in simple tension along the axis of the gage on steel whose Poisson's ratio is .285 (see Figure 4). Poisson's ratio is one of the elastic constants of a material. It is derived from the known effect that an axial elongation of a material is always accompanied by a lateral contraction. Conversely, longitudinal or axial compression will be accompanied by lateral expansion. By definition, therefore, Poisson's ratio is defined as the ratio of lateral unit deformation to lineal unit deformation. This ratio may be expressed by the equation

$$\varepsilon_n = \mu\, \varepsilon_1 \qquad (2)$$

where ε_1 is the unit strain along axis of the gage, ε_n is the unit transverse strain, and μ is Poisson's ratio.

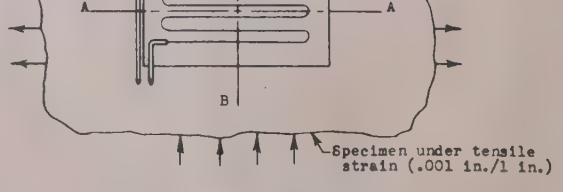

Figure 4

From the previous discussion on the strain measurement of Figure 3B it was determined that the transverse strain effected the precise measurement of the axial strain. Therefore, in order that the gage would give the correct measurement the

manufacturer assigns to the gage a smaller gage factor which absorbs the effect of the transverse sensitivity of the gage. The manufacturer's gage factor for the wire strain gage illustrated in Figure 3B would then be 1.93.

$$F_m = \frac{\frac{.2 - .0034 + .2}{100 + 6 + 100}}{\frac{.001}{1}}$$

$$F_m = 1.93$$

DERIVATIONS OF EQUATIONS FOR CORRECTING STRAIN GAGE MEASUREMENTS FOR TRANSVERSE SENSITIVITY OF THE GAGE USED

In applications involving two-dimensional strain the ratio of transverse (normal or perpendicular) to axial strain will, in general, differ from the ratio existing for simple tension (.285 for steel) - the condition under which the gage was calibrated by the manufacturer. Unless properly taken into account, the transverse sensitivity of such a gage may introduce an appreciable error in the results of the measurement.

The following table contains strain measurements made in a field of two dimensional strain with gages calibrated by the manufacturer. The transverse sensitivity of these gages is assumed to be 3% of the axial sensitivity.

Strain * in microinches per inch			Error in %
ε_1	ε_2	ε_a	$\frac{\varepsilon_a - \varepsilon_1}{\varepsilon_1} \times 100$
+1000	-285	+1000.0	0.0
+1000	+285	+1017.1	+1.7
+1000	+10,000	+1308.6	+30.9
+1000	-500	+993.6	-6.5
+1000	-10,000	+708.6	-29.2
-1000	+285	-1000.0	0.0
-285	+1000	-257.4	-9.7
0	+1000	+40.1	+301.0

ε_1 = true strain applied along axis of the gage.

ε_n = perpendicular component strain of ε_1 resulting from Poisson's effect.

ε_2 = true strain perpendicular to ε_1.

ε_a = apparent strain measured along axis of the gage (using F_m).

F_m = manufacturer's gage factor.

μ = Poisson's ratio.

k = coefficient of transverse sensitivity.

$$k = \frac{\text{transverse sensitivity } (F_T)}{\text{axial sensitivity } (F_A)}$$

*Tensile strain is conventionally assumed to be positive while compressive strain is considered negative.

The effect of transverse strain on the axial measurement e is equivalent to the difference between the true transverse strain and the perpendicular component strain of the axial true strain (resulting from Poisson's effect) times the coefficient of transverse sensitivity and is expressed as.

$$e = (\varepsilon_2 - \varepsilon_n)\, k \tag{3}$$

From the condition of the calibration

$$\varepsilon_n = (-\mu)\, \varepsilon_1$$

Substituting ε_n in equation (3) the effect of transverse strain on the axial measurement becomes

$$e = \left[\varepsilon_2 - (-\mu)\, \varepsilon_1\right] k \tag{4}$$

The apparent strain becomes then

$$\varepsilon_a = \varepsilon_1 + \left[\varepsilon_2 - (-\mu)\, \varepsilon_1\right] k \tag{5}$$

Using equation (5) let us consider the first measurement recorded in the above table.

$$\varepsilon_a = +1000 + \left[-285 - (-.285)\,(+1000)\right] .03$$

$$\varepsilon_a = +1000 + \left[-285 + 285\right] .03$$

$$\varepsilon_a = +1000$$

The results of the measurements recorded in the table indicate that the error in the apparent strain can be appreciable in two-dimensional strain measurements when the transverse sensitivity is ignored. In order to compensate for the transverse sensitivity of a gage with a manufacturer's gage factor, it is assumed that the resistance change of the gage is proportional to both axial and transverse strains. This assumption is expressed by the equation

$$\frac{\Delta R}{R} = F_A\, (\varepsilon_1 + k\varepsilon_n) \tag{6}$$

where F_A is the axial strain sensitivity of the gage.

From a previous discussion on the manufacturer's gage factor, it was learned that the gage factor supplied with the gage is the ratio of the unit change in resistance to the axial strain imposed under simple tension. This manufacturer's gage factor is then

$$F_m = \frac{\frac{\Delta R}{R}}{\varepsilon_1} \tag{7}$$

From equations (6) and (7)

$$\frac{\Delta R}{R} = F_m\, \varepsilon_1 = F_a\, (\varepsilon_1 + k\varepsilon_n) \tag{8}$$

and from the condition of calibration under simple tension,

$$\varepsilon_n = -\mu\, \varepsilon_1 \tag{9}$$

Then by substitution in equation (8)

$$F_m = F_A \frac{(\varepsilon_1 - \nu \varepsilon_1 k)}{\varepsilon_1}$$

$$F_m = F_A (1 - \nu k) \qquad (10)$$

The apparent strain ε_a obtained from the reading of any gage in a general strain field by using the factor F_m is

$$\varepsilon_a = \frac{\frac{\Delta R}{R}}{F_m}$$

and from equations (8) and (10)

$$\varepsilon_a = \frac{F_A (\varepsilon_1 + k\varepsilon_n)}{F_A (1 - \nu k)} \qquad (11)$$

The error e in the apparent strain resulting from ignoring the lateral correction is then

$$e = \frac{\varepsilon_a - \varepsilon_1}{\varepsilon_1} \qquad (12)$$

and by substitution with equation (11)

$$e = \left(\frac{\varepsilon_1 + k\varepsilon_n}{1 - \nu k} - \varepsilon_1 \right) \frac{1}{\varepsilon_1}$$

$$e = \frac{k}{1 - \nu k} \left(\frac{\varepsilon_n}{\varepsilon_1} + \nu \right) \qquad (13)$$

Equation (13) gives the error in the reading of any gage subjected to axial strain ε_1 and transverse strain ε_n. Tests involving two gages at right angles to each other, if the lateral sensitivity of the gages and the conditions of strain under which the gages were calibrated are given, it is possible to find the true strain by the use of two simultaneous equations based on equation (11).

ε_{a1} (apparent strain along axis of gage No. 1) is then

$$\varepsilon_{a1} = \frac{\varepsilon_1 + k\varepsilon_2}{1 - \nu k} \qquad (14)$$

(apparent strain along axis of gage No. 2) is then

$$\varepsilon_{a2} = \frac{\varepsilon_2 + k\varepsilon_1}{1 - \nu k} \qquad (15)$$

Both apparent strains are based upon the manufacturer's gage factor. The true strains determined from eqs. (14) and (15) are

$$\varepsilon_1 = \frac{(1 - \nu k)(\varepsilon_{a1} - k\varepsilon_{a2})}{1 - k^2} \qquad (16)$$

$$\varepsilon_2 = \frac{(1 - \nu k)(\varepsilon_{a2} - k\varepsilon_{a1})}{1 - k^2} \qquad (17)$$

CALIBRATION METHODS

The small change of resistance encountered in wire strain gage measurements must be detected and interpreted by the associated equipment in terms of strain. This requires a calibration of the gage (known change in resistance of gage) in terms of the output of the equipment. There are several methods of calibration. The most direct method is to apply a known strain on the gage and observe the output of the associated equipment. Other strains will then give a proportional output. Another method is to determine the change in voltage across the gage since this change is a function of the resistance change in the gage caused by the strain in the test specimen. This change in voltage can be evaluated in terms of the change in resistance. The strain acting on the gage can then be determined from equation (1). Still another method is to use the gage factor supplied by the manufacturer and insert a known calibrating resistance in parallel with the gage. The change in resistance of the gage can then be calculated and the output evaluated in terms of simulated strain. If ΔR is the gage resistance, and R_c is the calibrating resistor, R (change in resistance of wire gage) is

$$\Delta R = \frac{R_c R}{R_c + R} - R = -\frac{R^2}{R_c + R} \qquad (18)$$

The strain determined from equations (1) and (18) is then

$$\frac{\Delta L}{L} = \left(\frac{\frac{R^2}{R_c + R}}{R} \right) \frac{1}{F_m} = \frac{R}{(R_c + R) F_m} \qquad (19)$$

It should be noted that the gage factor calculation is based on zero lead resistance from gage. Any lead resistance, or resistance in series with gage, will change gage factor as shown below:

$$F_{mx} = F_m \frac{R}{(R + R_1)}$$

Where: F_{mx} = New gage factor
F_m = Original gage Factor
R = Resis. of gage used
R_1 = Added lead, or series, resis.

For calibration purposes, the new values of F_{mx} and $(R + R_1)$ should be substituted in equation (19) for F_m and R to find the resulting strain.

STRESS ANALYSIS

In the case of simple tension or compression, if a strain measurement is made in the direction of tension or compression, strain data can be evaluated in terms of stress from the relation

$$S = \varepsilon E \qquad (21)$$

where S is stress, ε is the observed strain and E is the modulus of elasticity of the material.

In the more general case of a two-dimensional stress field it is necessary to obtain at least 3 independent measurements of strain in order to establish the complete stress condition at a given point. Resistance wire gages grouped for this purpose, known as rosettes, are available commercially in 3 types of geometrical configuration called Rectangular, Tee-Delta, and Equiangular (Delta). These are shown schematically in Figures 6, 7 and 8. Each gage in the rosette arrangement is individually connected to a Strain Analyzer. The change in resistance of each gage of the rosette will then be a measure of the strain undergone in that particular direction due to the applied load.

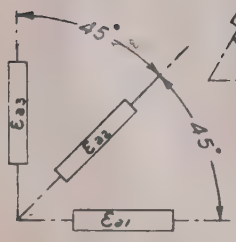

Figure 6
Rectangular

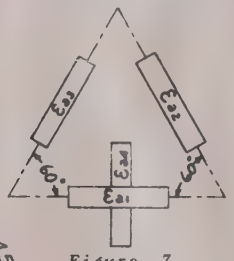

Figure 7
Tee - Delta

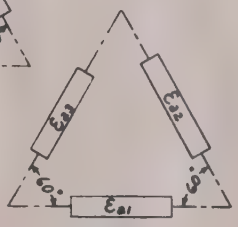

Figure 8
Equiangular

The complete stress conditions can then be defined by a set of equations computed for each rosette or by construction of Mohr's Circle. The mathematical treatment of the rosette gage and the construction of Mohr's Circle is beyond the scope of this instruction booklet. For further information, those interested are referred to the following literature.

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THE BRUSH DEVELOPMENT COMPANY

Instrument Division

MANUFACTURERS OF...

- *Direct Inking Oscillographs*
- *AC Amplifiers*
- *DC Amplifiers*
- *Carrier Amplifiers*
- *Surface Analyzers*
- *Universal Analyzers*
- *Contour and Displacement Analyzers*
- *Strain Analyzers*
- *Uniformity Analyzers*
- *Universal Bridge Switches*
- *Regulated Frequency Power Supplies*
- *WOW Meters*
- *Vibration Pickups*

and other acoustic and electronic instruments

"Universal Analyzer" MODEL BL-320

OPERATING INSTRUCTIONS

109515
8-50

OPERATING INSTRUCTIONS
"Universal Analyzer"
MODEL BL-320

GENERAL DESCRIPTION

The Brush "Universal Analyzer", Model BL-320, is a self-contained AC Wheatstone bridge, voltage amplifier, discriminator, and DC power amplifier. Though primarily designed to operate with a 120 ohm bridge circuit, it will operate with bridge circuits having a resistance from 50 to 1000 ohms. The active elements of the bridge can form either one, two, three, or four legs of the bridge. The output is designed to operate a Brush penmotor BL-902 and when properly matched will record uniformly from DC up to 100 cps. Due to physical limitations of the pen and penmotor the amplitude of the recording is a function of frequency. Frequencies up to 60 cps can be recorded safely with a 20 line peak displacement (40 lines peak-to-peak) and the maximum displacement at 100 cps is about 10 lines peak (20 lines peak-to-peak).

The four arms of the Wheatstone bridge terminate at the four binding posts located at the left front corner of the Analyzer. The bridge must be completed before the unit can be operated. This can be done in several ways depending on the device or number of strain gages to be used. Most strain gage pickups have all four arms of the bridge built in, so that by properly connecting the four leads from the pickup to the input terminals, the bridge circuit is complete.

Where strain gages are used by themselves one, two, three, or four arms of the bridge can be used actively. In any case the bridge circuit must be completed either by using dummy gages or precision wire-wound resistors. Regardless of the arrangement used, the elements or gages must be accurate to 1% or better in order to permit final balancing with the "C" and "R" balance controls.

SHORT OPERATING STEPS

The following procedure is based on the use of 120 ohm strain gages with a gage factor of 2.05, and leads having 1 ohm or less resistance.

1. Center the penmotor pen on chart before connecting to the "Universal Analyzer" by means of the centering lever at the side of the penmotor, with recorder running.
2. Connect the "Universal Analyzer" to the recorder with the interconnecting cable and twin outlet AC cord supplied, and turn on the AC power. (Ground the binding post at the back of the "Universal Analyzer".) After about twenty minutes the Analyzer will be "warmed up" and stabilized.
3. Complete the bridge with the desired number of 120 ohm strain gages and necessary resistors.
4. Turn the Analyzer attenuator to the "Off" position and the "DC Gain" control to the "DC Amplifier Only" position. Center pen with "DC Center" control.
5. Turn "DC Gain" control to "Bridge On" position. If the pen is deflected more than 2 lines see Item C in Service Notes regarding diode balance. If deflection is less than 2 lines, re-center pen with "DC Center" control.
6. The following procedure is for balancing the bridge. Turn "Attenuator" to the 200 position. Depress "Balance" switch and balance bridge with the "Bridge Balance (R) and (C)" controls, adjusting "(R)" control first. Balance is indicated by a minimum deflection of the pen from center on the chart. Continue this procedure changing the "Attenuator" each time until balance is obtained with the attenuator in the "1" position. Release "Balance" switch and center pen with "Bridge Balance (R)" control only.
7. Calibrate the bridge by pressing the "Calibrate" switch and adjusting the "AC Gain" control for 15 lines pen displacement. The Analyzer is now calibrated and ready to record any static or dynamic strains up to 100 cps at the following sensitivities.

   If only one 120 ohm gage is the active arm of the bridge, 1 line deflection is equal to 10 micro-inches/inch of strain. (Attenuator still in the "1" position.)

   If two arms of the bridge are used as active arms, 1 line deflection is equal to 5 micro-inches/inch of strain.

   If all four gages are active parts of the bridge, 1 line deflection is equal to 2.5 micro-inches/inch of strain.

   These sensitivities are based on the use of the standard 390,000 ohm calibration resistor supplied with the "Universal Analyzer".

Where pickups are used in which the manufacturer specifies a value of calibration resistance necessary to simulate a given value of the variable to be measured, this value of resistance can be substituted for the standard 390,000 ohm resistor and the deflection obtained can then be adjusted to a convenient value. The unit will then be calibrated in terms of the variable to be measured.

An example of this is as follows: Suppose a pressure pickup is used with which a 500,000 ohm calibration resistor is equivalent to 15 lbs/sq. in. of

pressure. The pickup is connected to the "Universal Analyzer" and the calibration resistor is inserted into the holder. The bridge is then balanced and with the "Attenuator" in the "1" position the "AC Gain" is adjusted for 15 lines deflection of the pen when the calibration button is depressed.

Each chart line represents 1 lb/sq. in. of pressure when the "Attenuator" is in the "1" position. When the "Attenuator" is in the "2" position each line represents 2 lbs. of pressure, etc.

For measurement of low pressures, the instrument may be calibrated with the "Attenuator" in the 2, 5, 10, or 20 position, giving sensitivities of 1/2, 1/5, 1/10, or 1/20 lb/sq. in./line respectively.

The "Attenuator" position to be used for calibration can be determined by trial. For example, assume that a 12 line deflection is obtained when the calibration switch is depressed with the "Attenuator" in the 5 position and maximum AC gain.

For convenience in reading, assume the gain to be adjusted for a 10 line deflection. Then the instrument will be calibrated to indicate pressures of 1.5, 0.6, and 0.3 lbs/sq. in./line for "Attenuator" positions of 5, 2, and 1 respectively.

BRIDGE CIRCUIT

The AC Wheatstone bridge circuit is shown in Figure 1.

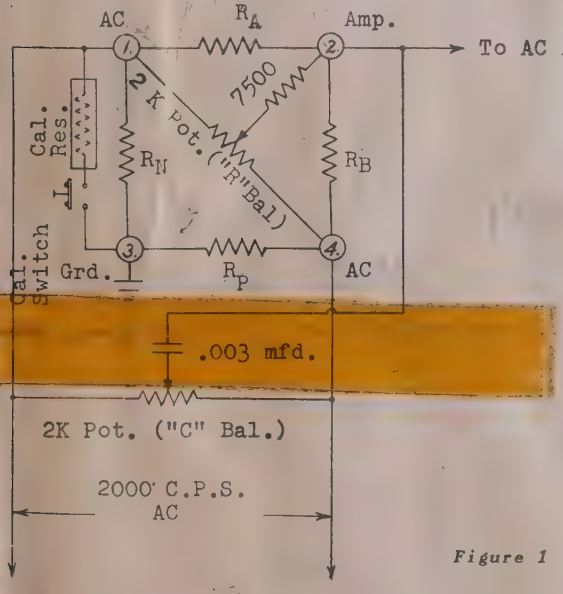

Figure 1

R_A, R_B, R_M, and R_P are the four arms of the bridge. In this circuit the following relationship is true:

$$\frac{R_N}{R_P} = \frac{R_A}{R_B}$$

Because the calibration resistor is switched across R_N, it is preferable to make this section of the circuit always an active member. In an arrangement for using only one arm as the active member, it is recommended that the active gage is used for R_N. R_P can be either a wire-wound precision resistor of equal value resistance or another identical gage mounted on some object and kept near the active gage to get temperature compensation. R_A and R_B should be wire-wound resistors of equal values (1% or better accuracy), not to exceed 1000 ohms for normal sensitivity. When two arms of the bridge are to be used as active members, R_N and R_P are used actively (both should be of equal value), with R_A and R_B being wire-wound resistors of equal value.

In order to facilitate fine balancing of the bridge the range of the "R" and "C" controls has been limited. The resistance of each arm should be kept within the 1% limits and the capacity of the leads kept to a minimum. In the event that long leads are necessary (20 ft. or more) using duplicate leads in all arms will help maintain the capacity balance. This practice has other beneficial effects besides maintaining close capacity balance, such as compensation for temperature effects on long leads and equalization of nonactive sections of each arm.

In most cases it is best to use shielded leads to prevent pickup from stray fields present throughout buildings or around equipment.

DESCRIPTION OF CONTROLS

All controls for the operation of the unit are located on the front panel with the exception of the "Off - On" switch, which is located on the back of the instrument. A description of these controls and their functions follows:

The four terminals located on the left side of the Bridge Circuit Control Panel are used to complete the bridge circuit, shown in Figure 1.

1. DC Gain A 5 megohm potentiometer with a S.P.D.T. switch. When in the "DC Amplifier Only" position the 5 meg. potentiometer (DC gain) is connected between the input jack (at front of the instrument) and the DC amplifier and serves as a gain control. When in the "Bridge On" position, the discriminator output is connected directly into the DC amplifier.
2. DC Center This control electrically centers penmotor pen when the "DC Gain" control is in either the "DC Amplifier Only" position with zero input, or in the "Bridge On" position with the "Attenuator" in the "Off" position.
3. Attenuator This control attenuates the output voltage of the bridge prior to applying it to the input of the AC amplifier. Eight steps are provided which range from zero to full bridge output voltage, giving an attenuation factor of 200, 100, 50, 20, 10, 5, 2, and 1. In addition

SPECIFICATIONS

Universal Analyzer, Model No. BL-320, complete with bridge, AC amplifier, discriminator, and DC amplifier:

Gage	Baldwin-Southwork SR-4 gage, type A - 1, or equivalent 120 ohm gage
Range of Measurable Strain	10 to 40,000 micro-inches per inch
Frequency Response (when used with Brush Direct-Inking Oscillograph	DC to 120 cps
Output Impedance	Approximately 50 ohms (not to be loaded with less than 1500 ohms)
Power Required	90 watts at 105 V to 125 V, 60 cps
Length x Width x Height	17-1/4" x 11" x 7-1/2"
Weight	30 lbs.
Tubes Required	Two 6SJ7, one 6C5, one 6H6, one 6SN7, two 6V6, two VR-150, one VR-105, one VR-75, one 5U4G
Fuse	2 amp., Littlefuse or equivalent
Circuit Diagram	309580

DC Amplifier contained in Universal Analyzer, Model BL-320, used with a Brush Direct-Inking Oscillograph:

Frequency Range	DC to 120 cps
Input Impedance	5 megohms
Normal Sensitivity	175 mv/one chart line

PRECAUTIONS

1. The pen should not be electrically biased to an extreme chart deflection with the "DC Center" control. Test specimen should be in an unstressed state or condition, if possible, while the equipment is being balanced and calibrated.

2. Make sure that the shielding of the cable to the strain gage is either totally insulated from, or positively grounded to, the object being tested. It is recommended that the "Universal Analyzer" be grounded directly and positively to the object being tested.

3. When using the "Universal Analyzer" in the most sensitive positions, it is recommended that connections to the bridge terminals be made by connecting the leads tightly under the terminal screws. If plug-in connections are used, any change in contact resistance due to erratic plug contact may be greater than the actual resistance change being measured in the strain gage.

4. For satisfactory results, line voltage should be between 105 V and 125 V. For extreme line voltage conditions, a regulating transformer should be used.

5. Because of the fact that the wire strain gage measures actual (surface or outer fiber) strain over the area which it covers (including torsion, bending, axial, and transverse strains), whereas readings obtained using other types of strain gages give approximately average strain throughout the section covered by the gage, results obtained using these two types of gages should not be compared. The strain indicated by a wire strain gage will not be the same as the strain indicated by a "cross-

sectional average-reading" type of gage unless the strain is pure tension or pure compression (no torsion, bending, or transverse strain). The user of the wire strain gage is warned that this type of gage gives only indication of surface or outer fiber strain and should not be interpreted as an average strain throughout the section. The effects of torsional, bending, or transverse strain can be rendered negligible by the use of two identical gages, properly connected, located opposite from each other on the object being tested.

6. The error introduced by mounting the strain gage skewed (at an angle) with respect to either the axial or transverse axis of the material being tested may be serious.

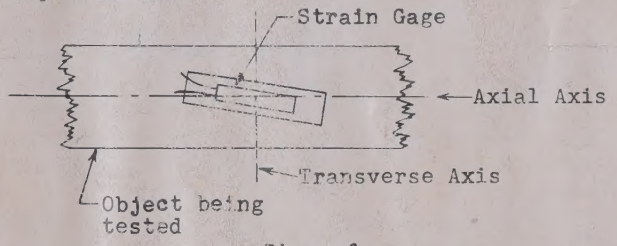

Figure 3

7. When using long leads to the pickup devices use identical leads as for reasons discussed in "Bridge Circuit" on Page 2.

8. The DC amplifier has a common ground with the chassis and a closed circuit input jack. These conditions should be observed when connecting the DC amplifier to power circuits.

9. A small error is introduced by the difference of distance between the neutral axis and the outer fiber, and the distance between the neutral axis and the center line of strain gage wire. (Due to thickness of cement, paper, and radius of strain gage wire.)

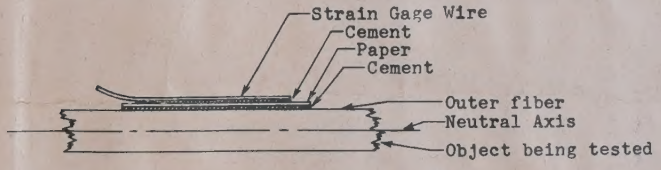

Figure 4

This error should be considered for extreme accuracy.

10. The values of R_n and R_p (See Fig. 1 on Page 2) should not be more than ± 1% (DC resistance) from one another. Likewise, the values of R_A and R_B should not be more than ± 1% from one another.

11. Care should be exercised to keep the strain gages or resistors sufficiently removed from any strong electromagnetic fields, so that the field will not have an effect upon the recording of the measurements being made.

SERVICE NOTES

Most of the information necessary for servicing is shown on the schematic circuit diagram (Drawing No. 309580). Since practically all parts are standard, it is recommended that only exact replacement parts be used, if and when replacement is necessary.

All testing of this unit should be done using either a 1500 ohm resistive load or a penmotor connected to the output terminals.

A. Each unit has been matched at the factory to the penmotor with which it is to be used. However, should the two units become unmatched, or if it is desired to use the amplifier with another penmotor, matching will again be necessary. The procedure to be used for matching is as follows:

1. Unscrew the four bridge terminal screws and then remove the four screws in the bottom of the case. Remove the unit from its case.

2. Center the penmotor mechanically (as described in Operating Instructions) and connect to the Analyzer. Connect a multiplug AC line cord to both units and plug into a 115 V - 60 cps supply. Turn the Analyzer on and allow to warm up for 20 minutes.

3. Turn the "DC Gain" control to the "DC Amplifier Only" position. Turn the penmotor on and center the pen with the "DC Center" control.

4. Feed a 1 V (RMS) 20 cps signal into the jack at the front of the unit and adjust the "DC Gain" to produce a pen deflection of 10 lines peak-to-peak. A medium or fast paper speed should be used. Next feed a 1 V (RMS) 80 cps signal into the unit, and observe the amplitude of the recording. This should also produce a deflection of 10 lines peak-to-peak. If the deflection is not 10 lines, adjust the frequency correction control labeled "Frequency" (25 K pot. located behind the 6V6 tube) until equal deflections are obtained from both 20 and 80 cps signals. Both the 20 cps signal and the 80 cps signal should produce the same deflection. It may be necessary to repeat the adjustments in order to obtain equal deflections.

B. An occasional check for drift is advisable. The "DC Gain" control is turned to the "DC Amplifier Only" position and, if necessary, the pen is centered with the "DC Center" control.

The unit should be thoroughly warmed up for this check (30 minutes) and a constant line voltage supply of 115 V should be provided. Should excessive drift occur (over 1 line per hour) replacement of V5 or V6 or any of the VR tubes may be necessary. Measurement of the static voltages in these stages should indicate what is necessary.

C. Adjustment of the diode balance is necessary only when the pen is deflected more than 2 lines from its center when the "DC Gain" control is turned from the "DC Amplifier Only" position to the "Bridge On" position ("Attenuator" in "Off" position).

To make this balance the case must be removed. This may be done by first removing the four binding post screws in the bridge panel and then removing the four screws in the bottom of the case. The cover can then be slipped off. With the unit thoroughly warmed up, and the "DC Gain" control in the "DC Amplifier Only" position, center pen by means of the "DC Center" control. Then put the "DC Gain" in the "Bridge On" position and bring the pen to exact center by means of the diode balance control (250 K potentiometer marked "Diode") located at the rear of the chassis behind the VR-75.

D. An occasional check for linearity is recommended. This can be done by setting up a "Universal Analyzer" with a gage in the dummy circuit and one in the test circuit. It is recommended that these gages are placed in an oil bath so that they remain at equal temperature. The bridge is then balanced perfectly with these gages connected. The "Calibrate" button is then depressed and a 15 line deflection to the right is obtained by varying "AC Gain" control. The pen is then brought back to zero by means of the "Bridge Bal. (R)" control maintaining the "Calibrate" button in the depressed position. Upon releasing the "Calibrate" button approximately a 15 line deflection to the left should be recorded. If a 15 line deflection is not obtained, this process should be repeated carefully two or three times to make absolutely certain that the nonlinearity does, or does not, exist.

If a nonlinearity exists, an adjustment of the padding condenser at the bottom of the amplifier is necessary.

This adjustment requires patience and skill because any change in the padding condenser shifts the zero besides changing the left and right deflections. It is recommended that any nonlinear amplifier be sent back to The Brush Development Company for this adjustment.

SPECIAL APPLICATIONS

The Brush "Universal Analyzer", Model BL-320 can also be used with an inductive type pickup. The primary impedance of the pickup at 2000 cps should be between 100 and 400 ohms. If it is less than 100 ohms it will load the bridge too heavily, and if it is greater than 400 ohms the sensitivity will be reduced. An increase in range of the pickup will also result in decreased sensitivity.

A four terminal bridge is necessary. The primary of the pickup is connected to the input of the bridge (terminals 1 and 4) with approximately .25 mfd. (± 2%) condensers from each input terminal to ground. A variable condenser (0 - .1 mfd.) is connected across the secondary of the pickup, which is also connected to the output of the bridge (terminals 2 and 3). The mechanical arrangement of the system is left to the user's discretion. Shielding of the coil and the leads is recommended for best results. When long leads are used, the primary and secondary leads should be separately shielded and the shields grounded.

A typical circuit connection for use with a Schaevitz inductive type pickup is shown in Figure 5.

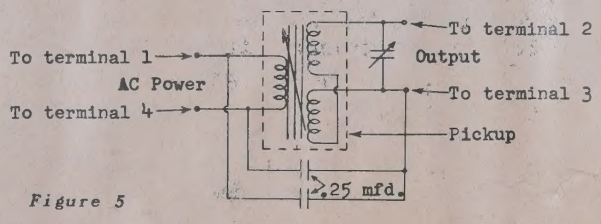

Figure 5

In order to complete the bridge circuit of tne BL-320, the AC power leads of the pickup are connected to terminals 1 and 4 of the bridge and the output leads of the pickup are connected to terminals 2 and 3 of the bridge. These connections apply to any pickups which have four external leads. If the polarity of reading obtained is reversed, simply interchange either the AC power leads, or the output leads.

Calculation of Calibrating Resistor for Use with the BL-320 UNIVERSAL ANALYZER and Various Types of Pickups

For the conventional 4-arm bridge, as shown in Fig. 6, the value of the proper calibrating resistor can be calculated from equation (1) below:

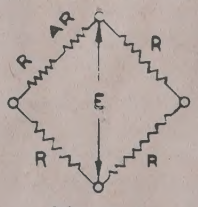

Figure 6

$$(1)\ R_c = \frac{-R}{2} - \frac{ER}{4E_{out}}$$

where R_c = calibrating resistance; R = resistance of 1 arm of bridge; E = applied voltage; E_{out} = output V. of bridge.

Some pickups are not the simple 4-arm bridge, but rather include a compensating resistor, as shown in Fig. 7.

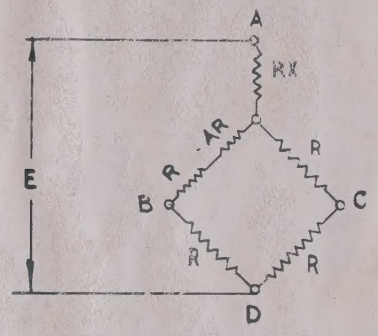

Figure 7

It can be determined whether the pickup circuit is the type shown in Fig. 6 or the type shown in Fig. 7, simply by measuring across the diagonally opposite connections of the bridge, which are the input and output terminals of the bridge. If the two measurements obtained are the same, then the circuit is that shown in Fig. 6. However, if the measurements are not the same, then the circuit is that shown in Fig. 7. In the latter case, the calibrating resistor can be calculated from equation (2) below:

$$(2)\ R_c = \frac{-(ER^2)-(2E_{out} \times R^2)-(3E_{out} \times RR_x)}{(4E_{out}) \times (R + R_x)}$$

where R_c = calibrating resistance; E = applied V.; R = resistance of 1 arm of bridge; R_x = compensating resistance; E_{out} = output V. of bridge.

The value of R_x is equal to the difference of the two values obtained by measuring between diagonally opposite corners of the bridge.

Proper connection of the pickup to the bridge terminals can be determined as follows: With reference to Fig. 7, measurements between terminals A-D and B-C should be made and recorded. Then, with terminals B-C (output terminals) connected together, measurements between terminals B-A and B-D should be made and recorded. The location of R_x in the circuit can be determined from the larger of the B-A and B-D measurements. The two terminals which gave the larger of the A-D and B-C measurements should be connected so that the R_x terminal is connected to bridge terminal #2 of the Analyzer and the other one to bridge terminal #3. The remaining two terminals are connected to bridge terminals #1 and #4 of the Analyzer.

A sample calculation of the calibrating resistor to be used with the Frederic Flader, Inc., Type PSB Pressure Pickup follows: (Range = 0-35 p.s.i.)

R_x = 47 (determined by measurements)

Following specified by mfgr.: E = applied V. = 18V.; E_{out} = .070V. (full scale); R = 300

$$R_c = \frac{-(ER^2)-(2E_{out} \times R^2)-(3E_{out} \times RR_x)}{(4E_{out}) \times (R + R_x)}$$

$$R_c = \frac{-1620000-12600-2961}{97.16}$$

$$R_c = 16{,}844$$

For use with the Flader Type PSB pickup (0-35 p.s.i.), the Universal Analyzer is balanced with the pickup properly connected and zero input, and the Attenuator in the "100" position. The attenuator setting is determined by trial and error adjustment of the Attenuator and gain control, with the computed value of calibrating resistor in the cartridge. With the calibration switch depressed, the Attenuator and gain are adjusted, starting with the Attenuator in the most sensitive position ("1" on the BL-320 and "10" on the BL-310S) to produce a convenient deflection. The calibrating resistor is then placed in the calibrating resistor cartridge of the Analyzer and screwed into place, and the gain control is adjusted to give a deflection of 17.5 lines with the

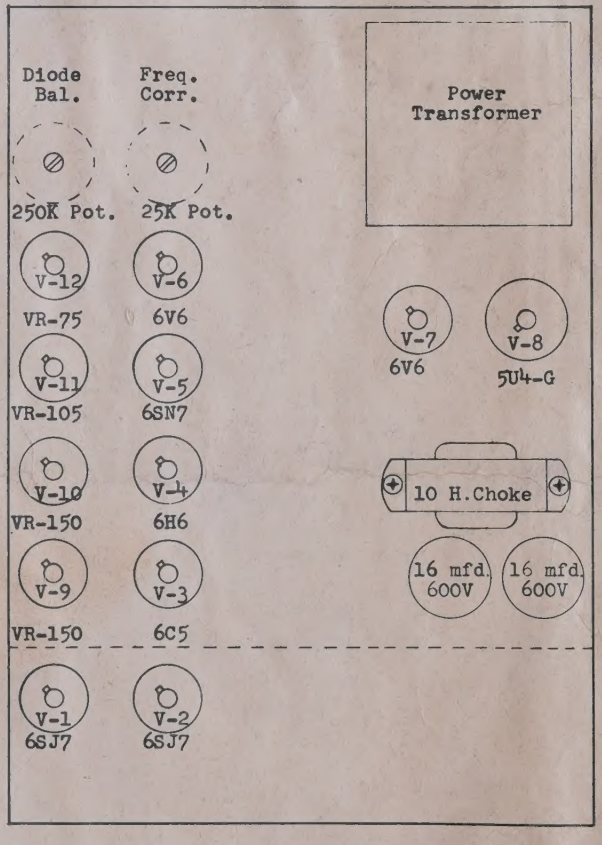

Figure No. 8 Top View of Chassis Showing Location of Tube Sockets and Controls. Universal Analyzer Model BL-320.